THE ONTARIO LAKESHORE CAPACITY SIMULATION MODEL

AN INTRODUCTION

The Ontario Lakeshore Capacity Simulation Model
An Introduction to the Model and its Role in Lakeshore Planning and Management

Integration Component
Lakeshore Capacity Study

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ACKNOWLEDGEMENT

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FOREWORD

The purpose of this document is to describe the model's capabilities and set out the boundaries within which it can operate. AT THIS WRITING THE ONTARIO LAKESHORE CAPACITY SIMULATION MODEL IS STILL EVOLVING AND IS NOT READY FOR IMPLEMENTATION. INTERNAL EVALUATION IS STILL UNDERWAY. Inquiries should be addressed to the Special Studies Section of this Ministry.

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1. INTRODUCTION

The construction of cottages, the development of services, i.e. roads, electrical power lines, boat docks, and the subsequent influx of cottage users changes the ecology of a lake, its shoreline and downstream lakes within the watershed.

Water quality is affected by the removal of vegetation for the preparation of the construction site, access roads, recreational facilities as well as the use and occupancy rate of cottages. Soil erosion is increased by these activities and runoff carries additional silt and nutrients to the lake. Nutrients enter the lake from cottage sewage disposal systems, and from fertilizer applied to grounds around cottage buildings. Nutrient enrichment of the lake water promotes the growth of algae and aquatic plants which, upon decomposition, lower oxygen levels in the lake. The impact of development on fish arises from changes in water quality, increased angling pressure and the removal of the near-shore fish habitat called the littoral zone. A reduction in water clarity and oxygen concentration creates unfavourable conditions for the growth and survival of fish. Rising angling pressure, resulting in an increasingly large fish harvest, will stress fish beyond the point where they are able to effectively reproduce and maintain their population size.

The littoral zone has special significance in that most activities in the fish life cycle, e.g., reproduction, feeding and growth, take place here. The removal of aquatic plants, rocks, dredging or dock construction in this area usually reduces the littoral zone's fish carrying capacity. Boating and other water sports also disturb the habitat.

The "coniferous fringe", the band of conifer trees that typically ring the shoreline of shield lakes, is very important to many wildlife species, while at the same time being the most desirable location for cottages. Wildlife habitat is modified by shoreland clearing and the selective removal of vegetation, resulting in changes in the size and the diversity of the wildlife population.

The lakeshore carrying capacity is recognized as the limit beyond which development and associated activities lead to undesirable changes in the lake environment. In initiating the Lakeshore Capacity Study, the Ontario government wanted to develop a tool which would be used to evaluate the impact of existing and proposed cottage development on inland lakes, based on their carrying capacities, and thereby prevent unacceptable changes in the environment. This is considered a more rational and cost-effective approach than permitting excessive cottage development and attempting remedial action after environmental problems arise.

The Ontario Lakeshore Capacity Simulation Model (OLCSM) was conceived in response to the need for such a management tool. Planners, developers, resource managers and policy makers are able to test various management scenarios and thereby acquire an understanding of the resiliency and development capacity of the lake under consideration (Figure 1).

Because it is a systematic repeatable method, the OLCSM can provide the foundation for streamlining and improving the quality of the subdivision approvals and official plans process specified in the Planning Act.

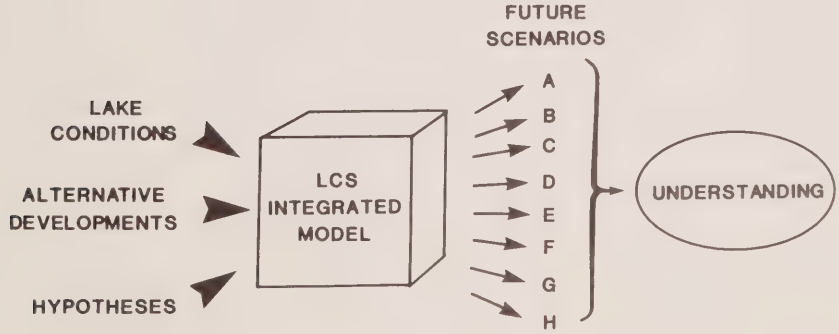


Figure 1 Model Input and Output

The model integrates five diverse research studies, blending wide ranging interests, recommendations and hypotheses into one tool. We see this tool as having wide applicability in the preparation of management strategies and as a means of increasing public awareness of the workings and sensitivity of lake – land communities. A good many of today's environmental management problems stem from poor information exchange between the researcher and the public user groups. With this model we reduce the complex natural system to a humanly manageable scale, retain only those linkages and pathways which specifically address cottage development and make it comprehensible to the layman.

The Lakeshore Capacity Study is an inter-ministerial project directed by the Ministry of Municipal Affairs and Housing with support from the ministries of Environment and Natural Resources. The Study is financed by Municipal Affairs and Housing.

The focus of the Lakeshore Capacity Study is the impact of shoreline cottage development on lakes in the Muskoka-Haliburton area of Ontario (Figure 2). The simulation model is based on findings reported by research groups from the three ministries (Burger, 1982; Dillon, 1982; Downing, 1982; Euler et al, 1982; McCombie, 1982; Harker, 1982).

Figure 2 Location of Study Area

2. BUILDING THE MODEL

The Adaptive Environmental Assessment and Management (AEAM) methodology was used to construct the OLCSM. It prescribed a coordinated interdisciplinary approach to model building. This relatively new method, developed by Holling and Walters[1] at the University of British Columbia, has been applied to selected studies around the world ranging from strategic land use planning in Austria to national resource strategy development in Thailand.

Canadian projects have been completed in British Columbia, Alberta, Ontario and New Brunswick. In most of these cases the resultant simulation models have been used to plot future management directions. However, the AEAM is still so new that long-term evaluation of its success has not been possible. Nevertheless, the ever increasing diversity of application of the AEAM is certainly some measure of its utility and perceived usefulness.

The adaptive approach takes into account the needs and concerns of the ultimate user, the resource manager. In our case the end product of the process was a model which reflected the interrelationships in the lake-watershed ecosystem to provide credible projections of change through time.

A critical ingredient of the AEAM methodology is short-term, intensive modelling workshops that involve potential users in the model's design. Participants in Workshop I (held in December 1980) included research scientists, planners, administrators and people in policy development positions from the three participating ministries. Although the focus of the workshop was to construct a simulation model of the lake-watershed system, the activity had a very important side effect: it encouraged communication and forced the participants to view their areas of interest in the context of the needs of others, promoting an interdisciplinary understanding of the problem. The simulation model was based not only on Lakeshore Capacity Study research but also published findings and the intuitive understanding of the system by the participants.

Workshop II (held in June 1981) incorporated, in the revised model, additional data collected after the first workshop and model refinements suggested by the participants. It also served as a focus for the review of all assumptions built into the model.

[1]For details please refer to Holling, C.S. (ed.). 1978. Adaptive Environmental Assessment and Management. Wiley Interscience, Toronto, 377 p.

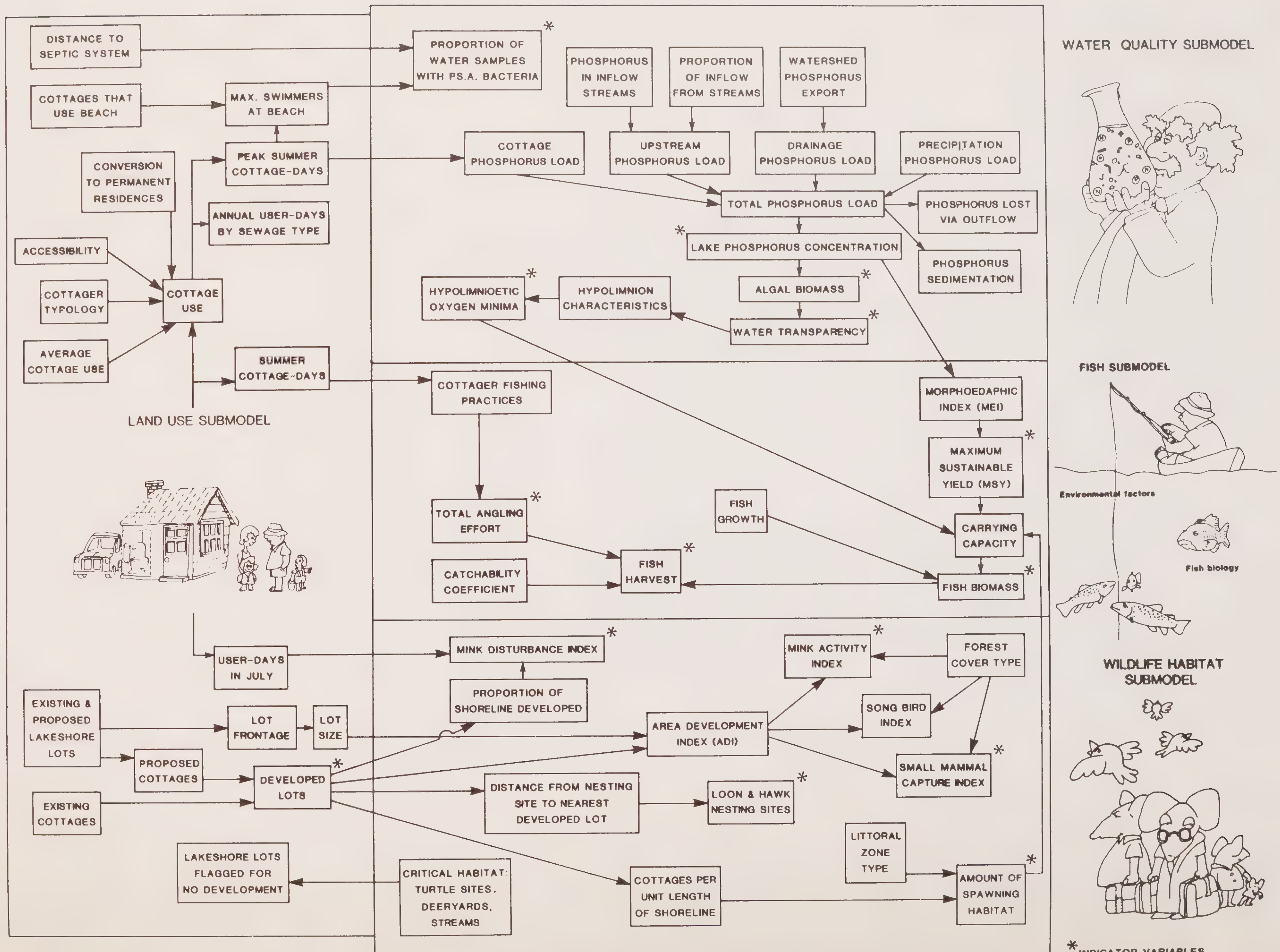


Figure 3 Flow Chart of Simulation Model

3. THE MODEL

The variables included in the model fall into four categories: land use, water quality, fisheries and wildlife-habitat. During the model building process each category, or submodel, was the responsibility of about eight people, including one modeller. Each subgroup developed the pieces of the submodel; the pieces were then linked (linkages established by participants) by the modellers. The internal operations of each submodel and the interactions between submodels are shown in Figure 3.

Linkages among the submodels are few with only the key interactions being considered. This reflects a guiding principle of the AEAM methodology which says that, "the parts of an ecological system should be connected to each other in a selective way that has implications for what should be measured" (Holling, 1978).

The model does not make any judgements about the priorities or permissible numerical limits of the indicators. Policies must be formulated by the regulating agencies, defining for each submodel the amount, percent or limits of change considered acceptable. There may be a range of values used as guidelines, depending on the policies of the individual agency.

4. WHAT THE MODEL CAN DO

The OLCSM simulates changes, through time, that occur in a lake, the surrounding lakeshore and in the watershed. The inner workings of the model, the "rules for change", are based on the current understanding of the lake-watershed ecosystem (Fig. 4). The effect of development in an upstream lake and land use practices within the watershed are incorporated in the model. Phosphorus levels can be evaluated in a chain of lakes beginning with the headwater lake and proceeding downstream. It is also possible to accommodate alternative configurations among connected lakes, e.g. two headwater lakes emptying into a common lake. The results of the simulation are displayed as indicator variables plotted for a user-specified interval of time (time-step) and duration. The indicators are measures of the performance of the system. When several alternative management strategies (actions) have been simulated, the indicator values may be compared and observed differences evaluated.

Actions can be introduced or terminated at any time during the simulation and, in effect, correspond to the controls which a manager might be able to implement as part of a management policy. The model permits the manager or policy-maker to see the repercussions of several options and, therefore, be better prepared to make decisions or recommendations regarding the appropriate course to follow. (Figure 4).

Whether a cottage subdivision should be approved or rejected, the lot size restricted, fishing restraints imposed or permanent occupancy limited are just a few of the possible management actions that can be examined. Rather than providing a single "magic" cottage capacity number, the simulation model will make apparent (to the user) the consequences of each of these hypothesized strategies.

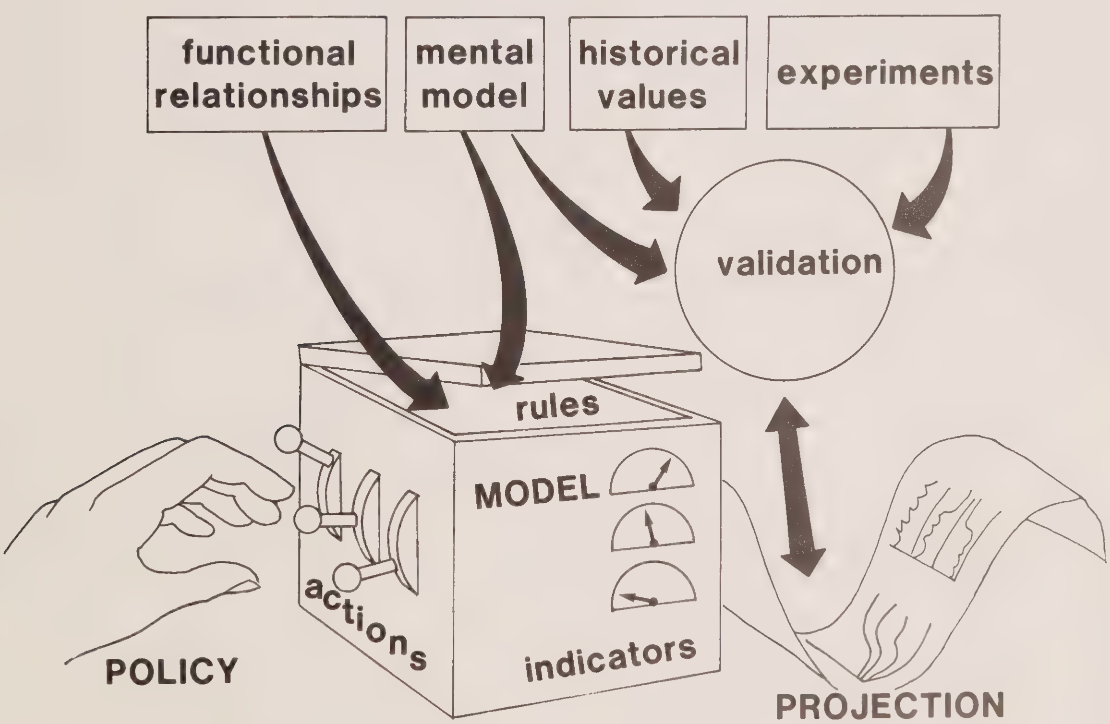


Figure 4 Relationship of Modelling Terms

5. LAND USE SUBMODEL

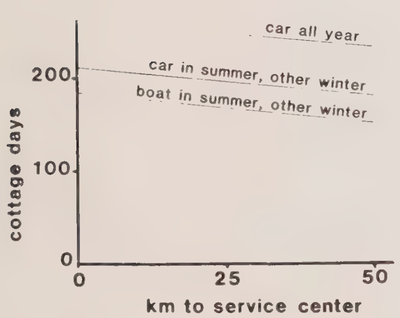
Cottage use, its frequency and intensity, was identified as a major environmental impact of lakeshore development. The primary function of the land use submodel is to predict the number of days the cottage is in use during the year (cottage-days), and the number of people occupying the cottage during each "cottage-day" of the year (user-days), for a given number of existing and proposed shoreline dwellings. This information is subsequently utilized in the water quality, fisheries and wildlife submodels.

COTTAGE OCCUPANCY

The land use submodel includes three equations for the prediction of cottage days: the accessibility, the cottager and the average. Because each predicts best under different sets of conditions, criteria are being developed by which the model will be able to choose the most appropriate equation. In the present version however, the user specifies which of the three methods will be activated in the simulation.

The *accessibility equation* is based on the hypothesis that access to a development and the services provided determine, to a large extent, the amount of use a cottage gets each year (Figure 5). For example, the travel mode (TMODE) variable reflects higher cottage use when the cottage is accessible by road and lower cottage use when it has water access only. Similarly ease of access is affected by the distance a cottager must travel on unpaved roads (MAXPOORX) when visiting the cottage. A third variable related to access is the distance to the nearest urban service center in the region (DISTSUMH). While weekend cottagers have little or no need of local services, those who stay longer need to replenish their supplies periodically. Year-round cottage residents need a wider range of services including financial and medical services. Cottages closer to larger towns are more likely to be used as principal residences than those farther away.

$$\text{cottage days} = 83 + 93\ \text{TMODE1} + 23\ \text{TMODE2} + 22\ \text{TMODE3} - .52\ \text{DISTSUMH} + .32\ \text{MAXPOORX}$$



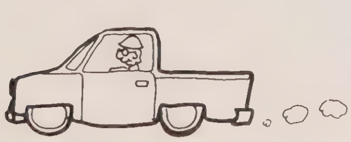
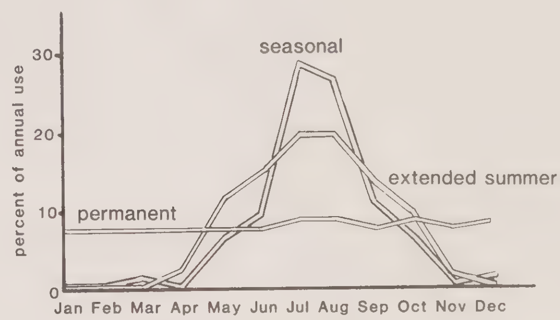


Figure 5 Accessibility Graph

The *cottager equation* is based primarily on the pattern of cottage use, although it does include several accessibility variables (Figure 6). Three distinct groups of cottage users were identified. The seasonal group is the sum of those people who use their cottages on weekdays, weekends, or long weekends, in spring, summer and fall. Cottagers who report high levels of use throughout spring, summer and fall are included in the extended summer use group. Permanent residents comprise the third grouping.



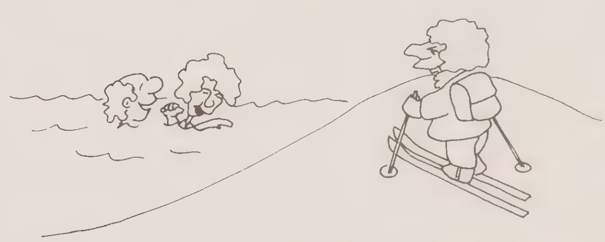


Figure 6 Distribution of Annual User-Days Over Months

The cottage use pattern inherent in these groups can be thought of as the end result of all the diverse decisions made by cottagers, based on internal (i.e. socio-economic characteristics such as family income, occupation) and external (i.e. cost of gasoline, amount of leisure time) factors. By matching access characteristics of a surveyed lake with those for an unsurveyed lake, the unsurveyed

lake may be assigned the surveyed (or benchmark) lake's use pattern. This use pattern is then used to estimate the total cottage occupancy rate on the unsurveyed lake. It is the mean annual use associated with each of the groups, i.e. seasonal = 75d, extended summer = 171d and permanent = 365d, not the curves shown in Figure 6, which is used in the submodel calculations. It is assumed that the cottagers on the benchmark lake have habits similar to those of the cottagers on the unsurveyed lake.

The *average equation* estimates cottage use by using the average use figure reported from the cottager survey.

The submodel is capable of evaluating several single-tier developments concurrently on a given lake. Information on the number and size of existing and proposed lots and the number of existing cottages (information needed by the other submodels) originates in the land use submodel. Using specified rates of cottage construction for the existing and each of the proposed developments, the submodel calculates the number of cottages added to the lake each year in terms of the developed lot frontage. Lot size (ha) is used to predict the area of the lot disturbed, an important measure in the wildlife submodel.

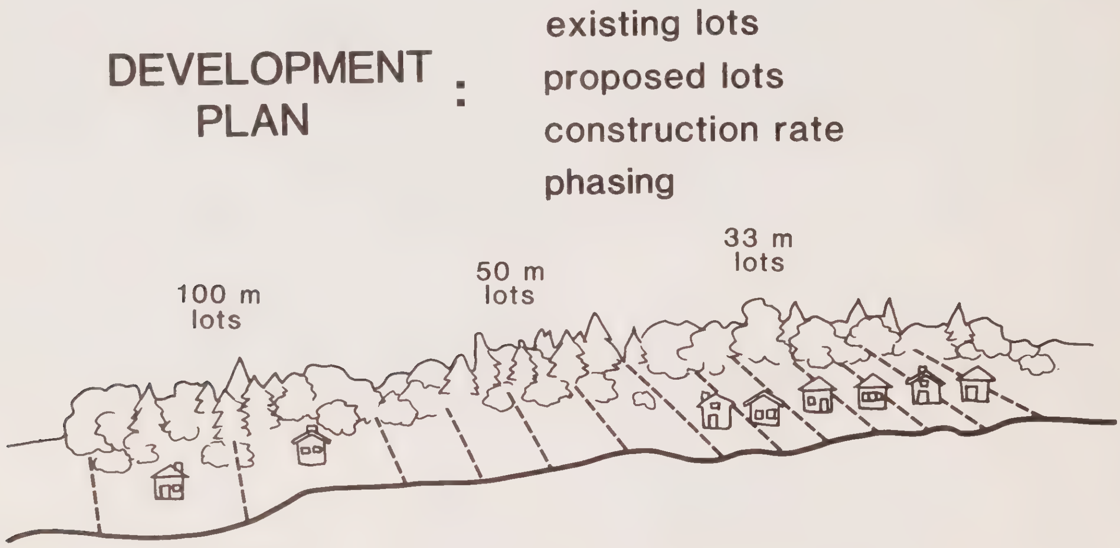


Figure 7 An Example of Waterfront Development

SWIMMING

Swimmer density at beaches is calculated in the land use submodel. This number is then used to estimate the risk of water-borne ear infection (Figure 8). Using the "worst case" approach, the cottage occupancy during the day of peak use for each summer month was used as the maximum "pool" of potential beach swimmers. The "pool" was adjusted to the proportion of the cottages in which members of the household swim at a beach. A further reduction by half was used to compute the proportion of the household who actually go to the beach and swim during the peak mid-day hours on the day experiencing the greatest cottage use.

swimmers = cottages X % occupied* X

1/2 (% cottages with swimmers swimming at beach) X users/cottage* X % swimming 11 am to 2 pm

*Highest use day in each summer month (June to Sept.)

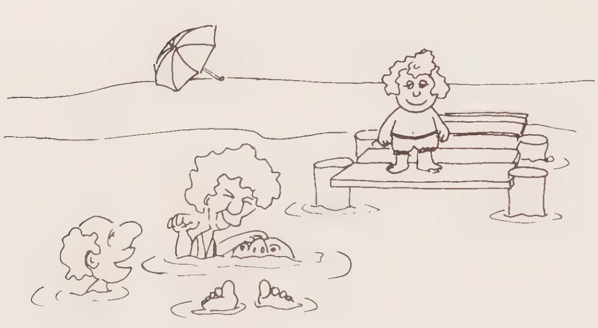


Figure 8 Swimmers Equation

MANAGEMENT STRATEGIES

Some examples of the management options that can be imposed on the land use submodel include limitations on lot size, road access to cottage, rate of cottage construction, rate of conversion to permanent residency and maximum number of lots in the proposed subdivision. Restrictions may be started or stopped at a time specified in the simulation, i.e. construction in a proposed subdivision may be delayed for several years.

6. WATER QUALITY SUBMODEL

The water quality submodel is divided into two parts: one predicts the nutrient level, or trophic status, of the lake and the other is concerned with the health related microbiology of lake water.

TROPHIC STATUS

The focus of the trophic status portion is phosphorus as it is the nutrient most frequently controlling algae and plant production in north-temperate lakes. High phosphorus levels are associated with the pollution of lakes and decrease in water quality, i.e. water clarity and dissolved oxygen.

phosphorus is added to the phosphorus in precipitation falling directly on the lake, the watershed basin and from the phosphorus coming from inflow streams.

The artificial phosphorus loading, i.e. from sewage, is calculated from the yearly per capita estimate of phosphorus supplied in sewage and the number of cottage user-days for a given lake. The proportion of this phosphorus that will reach the lake is related to the number of user-days associated with each type of sewage disposal system. Holding tanks release no phosphorus to the lake because the tanks are pumped out periodically

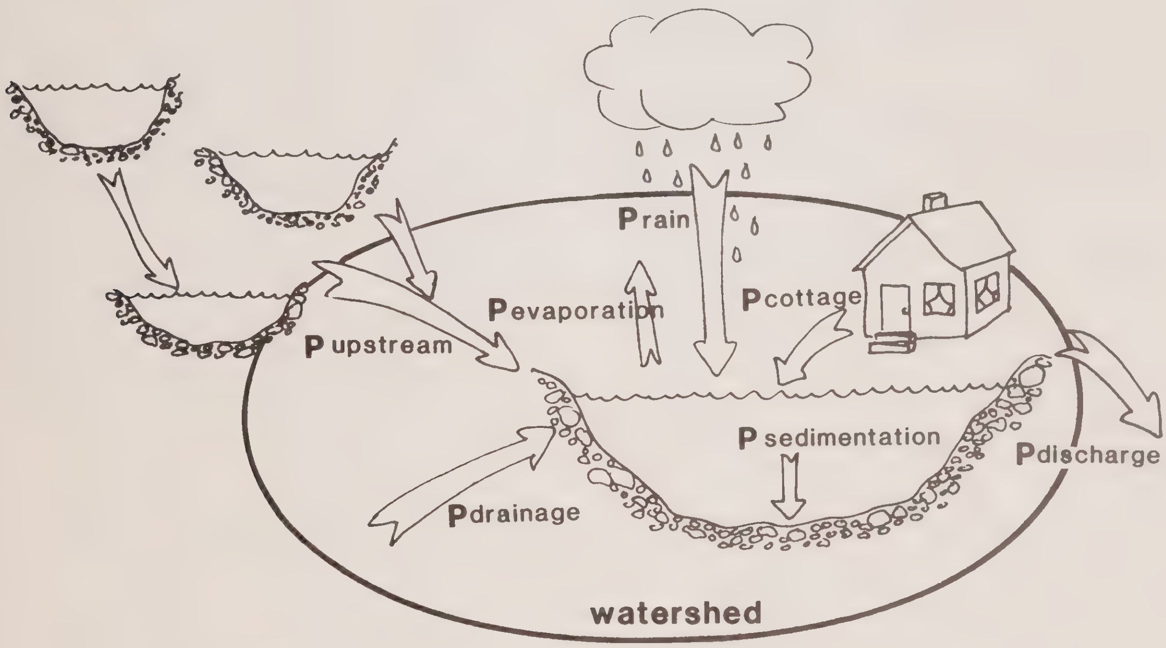


Figure 9 Input and Output of Phosphorus

Lake phosphorus additions consist of natural and artificial inputs, retention in the sediment and release through outflow streams (Figure 9). From a knowledge of the geology and land use in the drainage basin, an estimate is made of the total phosphorus exported per unit of watershed which, combined with the drainage area, provides an estimate of the total phosphorus supplied to the lake from the drainage basin. To calculate the total natural lake phosphorus loading, the drainage basin

and the sludge removed to treatment plants outside the watershed. Lagoons are sewage settling basins that are partially drained in the spring, at which time about 15% of the sewage-phosphorus is released. Septic systems, the dominant sewage disposal system, provide a subterranean release of the sewage effluent. The amount of phosphorus from the septic effluent reaching the lake is calculated from the binding capacity of the soil reservoir and the phosphorus leakage rate.

The lake phosphorus concentration is predicted from the total phosphorus input (natural and artificial), the phosphorus sedimentation rate and the lake flushing rate.

The flushing rate represents the number of times the lake volume is completely replaced in a year. It is related to the amount of surface runoff which is derived from long-term areal runoff data which have been mapped for large parts of Ontario.

Lake phosphorus concentrations are simulated (predicted) seasonally. Where development is proposed for a lake in a chain of lakes, phosphorus calculations proceed from the uppermost lake downstream.

The summer mean algal production and water transparency (secchi depth) are water quality indicators that are calculated from the lake phosphorus concentration (Figure 10).

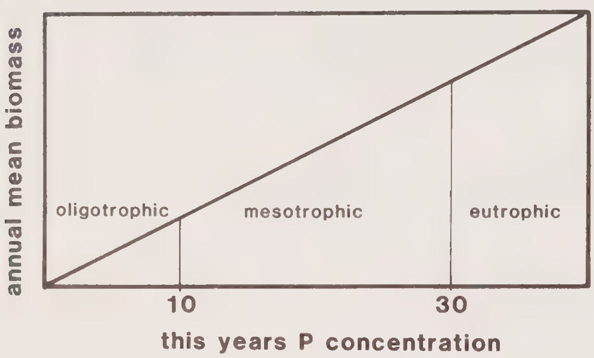


Figure 10 Algal Biomass

Other useful indicators of water quality are the summer and winter oxygen concentration minima. These are important as indicators of the quality of the trout habitat and are used in the fisheries submodel. During the summer, oxygen is consumed in the deeper layers of the lake, the hypolimnion, resulting in steadily declining concentrations. The summer oxygen minimum is derived using an equation which estimates the monthly oxygen depletion rate in the hypolimnion. Beginning in the spring, when the oxygen concentration is assumed to be at its maximum, and at monthly intervals for the duration of the summer, the oxygen depletion rate is subtracted from the oxygen concentration of the previous month. The summer oxygen minimum is the concentration in the hypolimnion at the end of the summer season. A similar method is used to calculate the winter oxygen minimum.

We intend to include in the model the probability of complete mixing (or turnover) based on a measure of the lake's exposure to wind. Lakes that lie in a high-relief topography often experience only partial turnover. If a lake is identified in this category the spring oxygen concentration at turnover will be increased only in proportion to the amount of mixing that takes place.

MICROBIOLOGY

The microbiology portion of the submodel predicts the proportion of water samples with detectable levels of the bacterium *Pseudomonas aeruginosa.* This bacterium causes an infection of the outer ear known as "swimmer's ear". Research indicates that it is contracted when swimming in water containing *P. aeruginosa.* As the main sources of the bacteria on the Study's lakes are swimmers' ears, the proportion of samples with *P. aeruginosa* is higher at swimming beaches than at other locations along the shoreline (Figure 11). In the water quality submodel, the presence of sewage systems less than 50 m from the beach increases the proportion of water samples with *P. aeruginosa* for any level of swimmer density. The proportion is increased further by beach water temperatures above 20°C. Bacteria multiply more rapidly at these water temperatures.

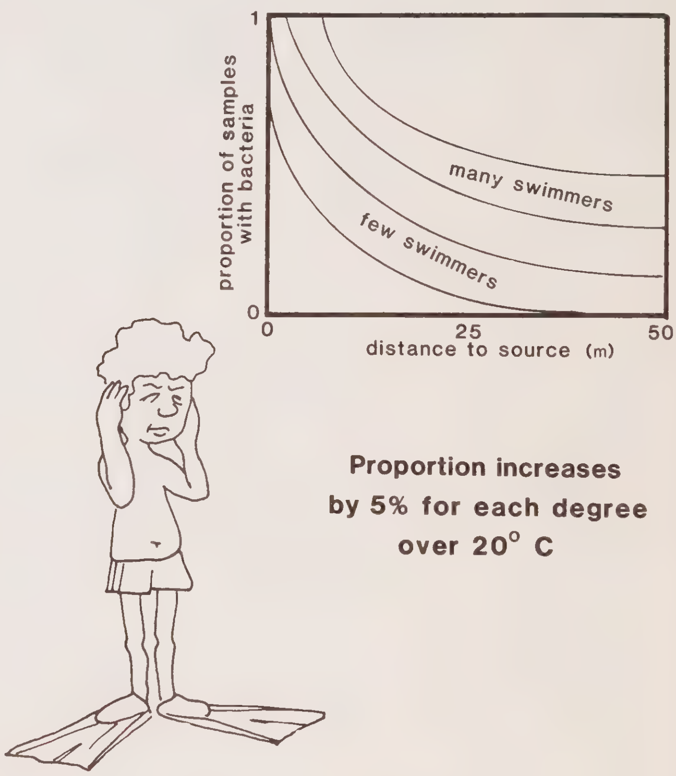


Figure 11 Ear Infections

MANAGEMENT STRATEGIES

Several alternative management strategies include specifying a maximum lake phosphorus concentration; varying the sewage system type; binding capacity of soil or phosphorus leakage rate for a proposed development; altering the rate of cottage conversion to permanent residency or changing the length or number of beaches.

7. FISHERIES SUBMODEL

The fisheries submodel represents a characteristic sport fish population that is sensitive to the effects of cottage development. The impacts investigated are changes in the amount of fishing, oxygen concentrations and alterations of the littoral zone habitat. The two species which were selected for inclusion in the submodel are lake trout and smallmouth bass because they are important to the sport fisheries in Ontario, do not compete for the same resource base and are sensitive to different aspects of cottage development. The lake trout responds negatively to nutrient enrichment, the smallmouth bass negatively to littoral zone disruption and positively (at least initially) to enrichment. As well, the bass is considered a "warm-water" fish while the trout is a "cold-water" species.

The foundation of the submodel is Ryder's fish yield equation (Ryder, 1965) and his morphoedaphic index (MEI). It is based on the premise that the total fish yield is a function of the physical and chemical lake characteristics embodied in mean lake depth and total dissolved minerals respectively (Figure 12). As several researchers (e.g. Matuszek, 1978) have suggested that Ryder's yield estimate represents a maximum sustained yield (MSY) level, this hypothesis was built into the model. The MSY is defined as the maximum weight of sport fish that can be removed from the lake annually without significantly altering the kinds and sizes of fish caught. If the angler harvest exceeds the MSY, the fishery is endangered. However, if the harvest is less than the MSY, there are presumably fish to spare and room for more fishing. To ensure that neither species is overfished, the MSY was apportioned to each species using data from the Ontario fish harvest surveys. Lake trout, smallmouth bass and other fish were apportioned 25%, 50% and 25% of the predicted yield respectively.

Because the MEI is not implicitly responsive to changes in phosphorus concentrations the submodel includes a sequence that modifies the MEI with respect to lake phosphorus levels. The adjusted MEI is then used to estimate the MSY.

The carrying capacity (K) for each species, the maximum production under optimum conditions, is modified by environmental factors that erode or enhance the ability of the lake to support a species. A change in carrying capacity has strong implications for lake management. If carrying capacity changes, the same catch can result in either under- or over-fishing at the same biomass level (Figure 13).

$$\text{MEI} = \frac{\text{total dissolved solids}}{\text{mean depth of lake}}$$

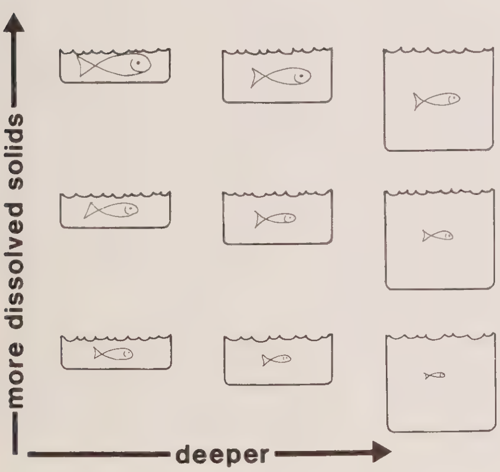


Figure 12 Morphoedaphic Index

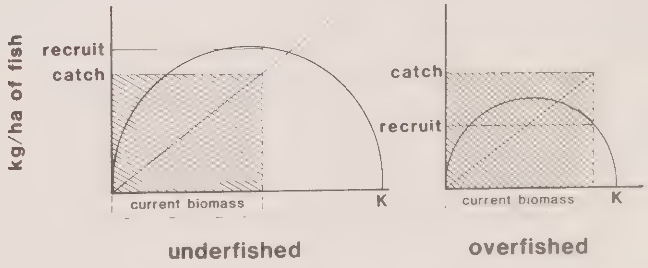


Figure 13 Change in Carrying Capacity (K)

The carrying capacity of lake trout is reduced by low levels of dissolved oxygen in the hypolimnion. Oxygen concentrations greater than 5 mg/L indicate good habitat for trout while oxygen concentrations below this level steadily reduce the trout carrying capacity. The effect is most severe at 2 mg/L when the carrying capacity is reduced to zero. (Figure 14).

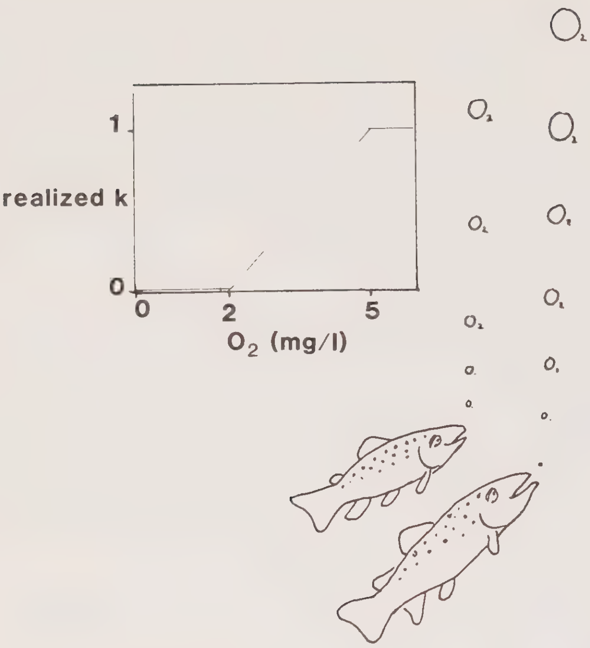


Figure 14 Oxygen Effect on Trout

Similarly, the smallmouth bass carrying capacity is altered by changes in the amount of preferred littoral zone habitat. Smallmouth bass depend on specific types of littoral zone bottom for their spawning, nursery and feeding success. In order to relate the availability of littoral zone habitat to fish productivity for the lake, the carrying capacity is reduced proportionately to the reduction in habitat.

Angling effort is derived from a survey of cottagers and a creel census (survey of fishermen and their catch) (Figure 15). Summer cottager angling effort is related to the number of days a cottage is used (cottage days) in summer, the proportion of cottages whose occupants report fishing activity, the number of anglers per cottage, the number of hours of angling per day and the proportion of cottage-days during which fishing occurs (Figure 15). These numbers, except for cottage-days, are overall "global" averages.

The summer non-cottager angling effort is based on the level of fishing by the summer cottagers. This indirect approach is used because of the difficulty in obtaining information on non-cottagers entering the lake from resorts, parks, marinas and boat ramps. The assumption is that if there is public boat access the quality of the fishery, as evidenced in cottager effort, will be reflected in the non-cottager angling practices. For the same reason, winter angling, almost exclusively by non-cottagers, is assumed to be a function of winter access and summer fishing patterns. Total angling effort (in terms of angler hours per hectare) is the sum of the angling effort in summer and winter.

The catchability coefficient (q) represents the proportion of the fish population caught per angler hour of fishing. It is higher for smallmouth bass than for lake trout. Data on different fishing methods (MNR, 1978) suggest that lake trout are more easily caught in the winter than in the summer; the catchability coefficient reflects this and is slightly higher in winter.

hours Effort = cottage days x % cottages with anglers

x fishermen per cottage x % days fishing x hours per trip

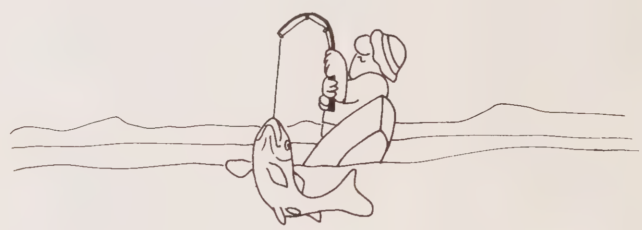


Figure 15 Angling Effort

MANAGEMENT STRATEGIES

The fisheries submodel permits the user to evaluate several different fish management strategies. The fishing season, which runs from May through September for the summer season and January through March for the winter season, can be changed by omitting one or more months from either season. The summer or winter fishery can be turned off completely to assess its effect on the trout population. In order to reduce the harvest, a limit may be placed on the allowable catch.

8. WILDLIFE SUBMODEL

The effect of cottage development on wildlife is calculated indirectly from changes in the shoreland vegetation. It is termed the "habitat approach" because it emphasizes wildlife habitat rather than the population dynamics of a given species. Shoreline development is accompanied by alterations in the structure and species composition of shoreland vegetation. During the initial phases of development, the trees, shrubs and ground vegetation are cleared for cottage construction and for the associated access roads, transmission line corridors and lakeside recreational facilities. Subsequently, cottagers clear portions of the shoreline for lawns, patios and beaches, and selectively remove less preferred plant species. Weeds in the littoral zone are also removed to improve boat access and swimming.

Because wildlife depends on vegetation as a source of food and shelter, disturbance of the vegetation results in changes to the wildlife population. In order to keep track of the wildlife and littoral zone habitat changes for specific locations around the lake the lakeshore is divided into uniform segments. The segments are numbered consecutively and assigned a shoreland forest cover type (i.e. coniferous, mixed or deciduous) and an offshore littoral zone habitat type (i.e. weedy or rocky) (Figure 16). This numbering scheme allows the user to pinpoint sensitive areas on a lake and identify the amount of transitional or "edge" habitat within segments. The variety and density of wildlife species, particularly songbirds, is often greatest in these areas.

The area of disturbance on a cottage lot was found to be relatively uniform and unrelated to lot size (Figure 17). Developments on large lots disturb a smaller proportion of the lakeshore habitat than those on smaller lots. By using the average lot size for each segment, it was possible to calculate the area development index (ADI) which is a measure of the proportion of the segment that is disturbed.

The wildlife species referred to in the submodel vary in their tolerance to development; some are able to utilize disturbed areas while others are sensitive to minor changes in the vegetation composition.

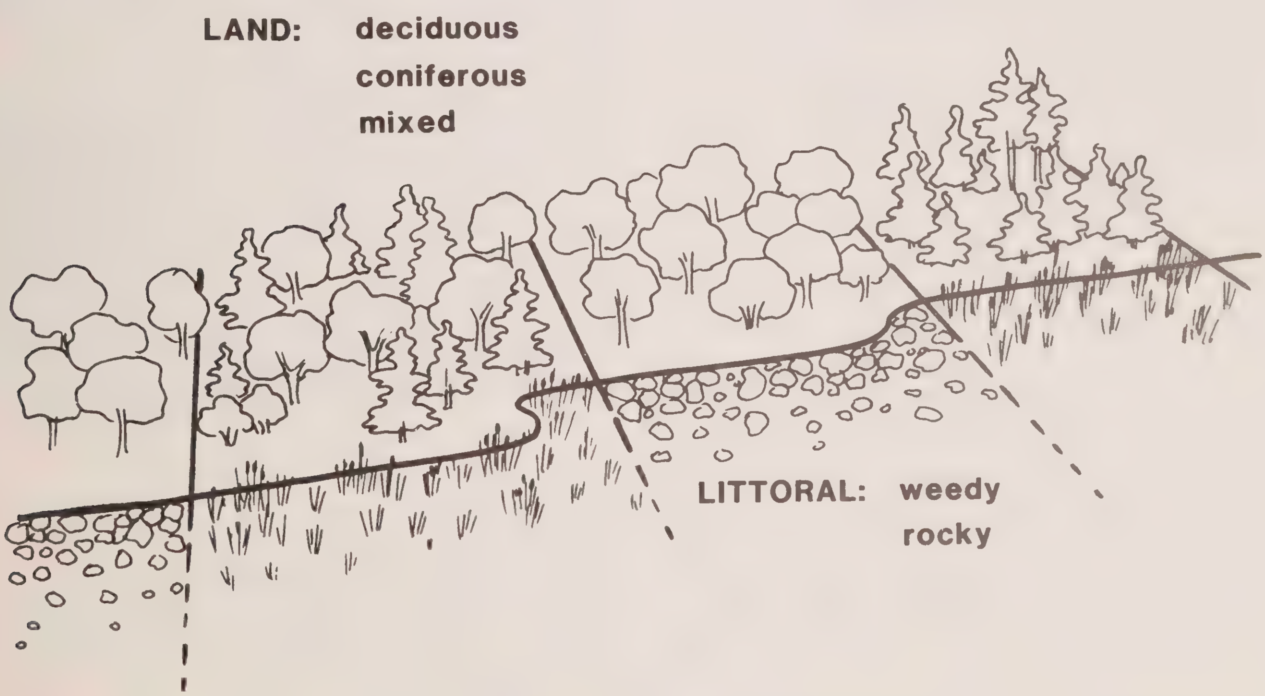


Figure 16 Lakeshore Description

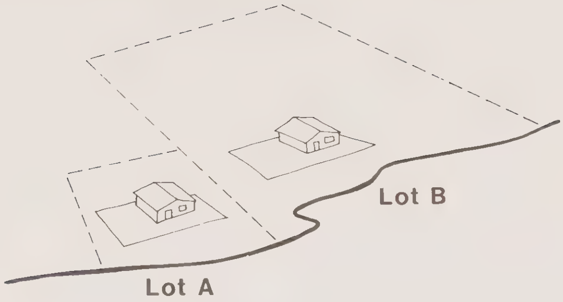
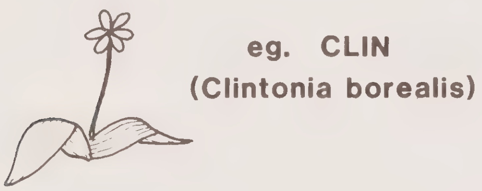


Figure 17 Proportion of Lot Disturbed

SMALL MAMMALS

Included in the submodel are seven small mammal species, the largest being the red squirrel. Having identified plant species groupings with each forest cover type and a range of ADI values, a relationship was derived between the type and number of plants per unit area, the ADI, forest cover and the small mammal capture-index (Figure 18). Therefore, to predict how much



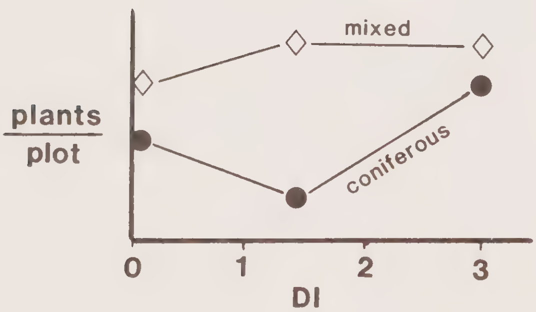


Figure 18 Change in Vegetation with Development

of a species' habitat will be degraded by development, one only needs to identify the forest cover types and the ADI's around the lake. The small mammal capture-index for each species is an indication of the population numbers that accompany these combinations of shoreline vegetation. The assumption is that if you catch more jumping mice in vegetation group a than b, a is a better habitat for that species and the alteration of that habitat would affect the wildlife population.

SONGBIRDS

"Songbirds" refer to the small perching birds such as robins and bluebirds. The evaluation of the impact of development on songbirds is based on the probable number of breeding pairs of each species per shoreline segment and is calculated from an estimate of the area of good breeding habitat. Given a particular vegetation type the probability of a bird species occurring on a particular segment of shoreline is proportional to the level of development (Figure 19).

The coefficient of community is an indicator of impact on the songbird community. It measures the amount of change in the bird community that occurs in response to development.

disturbance	deciduous			mixed or coniferous		
number of adjacent segments disturbed	0	1	2	0	1	2
low	.6	.5	.3	.9	.7	.5
medium	.3	.3	.3	.5	.5	.5
high	.2	.2	.2	.4	.4	.4

Figure 19 Probability of Finding a Breeding Pair of Ovenbirds

MINK

Two measures of the impact on mink were developed; a mink activity index and a mink disturbance index. As the proportion of the developed shoreline increases, mink disturbance rises while mink activity wanes. This situation is aggravated as the number of cottage user-days increase during the mink's reproduction period.

LOONS AND HAWKS

One of the major factors limiting reproductive success for hawks and loons is the availability of adequate nesting areas. For a location to be considered a high quality nesting site it must be a minimum distance from the closest shoreline dwelling. For each species, the user identifies the shoreline segments in which potential nesting sites are located. The reduction in the quality of the nesting site is calculated when the site is located between the minimum and the "safe" survival distance from a cottage.

DEER, TURTLES, STREAMS

Segments which contain turtle nesting sites, deer yards or streams are flagged as critical habitats. If development threatens these locations, the model will indicate a warning to that effect. Streams are particularly important as they provide breeding grounds for amphibians and provide valuable feeding sites, shelter and travel lanes for many wildlife species.

LITTORAL ZONE

The littoral zone hosts the spawning, nursing and feeding activity for many fish species. Smallmouth bass occupy the littoral zone during a large part of their life. Changes in this habitat affect the nest and population densities depending on which lake bottom type is disturbed (Figure 20). For example, aquatic weed beds are the most

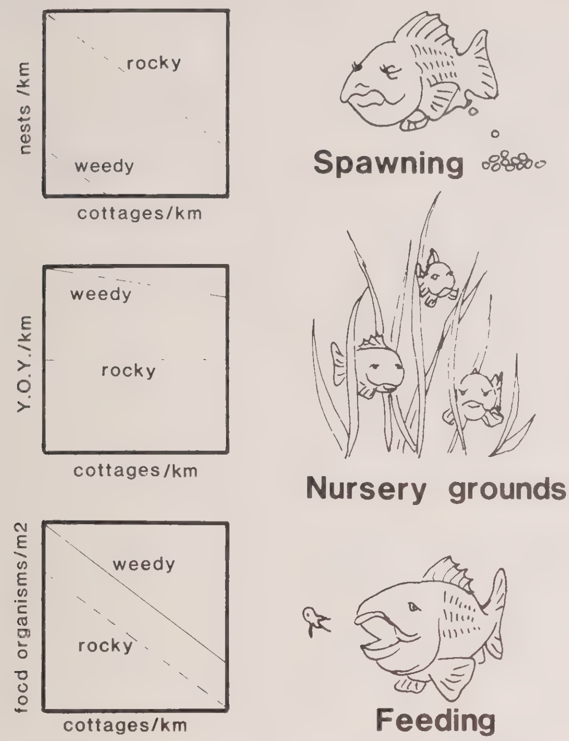


Figure 20 Use of Littoral Zone by Smallmouth Bass

important feeding areas for smallmouth bass and when plants are removed to form beaches the usable bass feeding ground is depleted. The smallmouth bass population in the littoral zone is a function of the shoreline development in terms of the number of cottages per 1000 m of shoreline.

MANAGEMENT STRATEGIES

Examples of management options include restrictions on the minimum lot size, the maximum number of cottages and lot development.

9. MODEL STATUS

With the model adjustments and refinements (stemming from Workshop II) in place, the model will now undergo testing with data from other studies where the history and present condition of the lakes are known. Actual changes in the lake-watershed system can then be compared with model predictions. This testing must be completed before the model can be applied in any actual subdivision evaluation. The OLCSM provides no statistical error estimates. The model input data scheme, planned as a 'conversational' system, needs to be prepared. At present, the user must fill in an input data sheet and then transfer these data to the computer. Finally, the selection of which 'Land Use' equation the model is to use must be made by the user. In the future these tasks will be a part of the internal workings of the model.

In the present version of the model, the variables affected by acid precipitation are flagged to alert users to the possibility of errors in indicator values due to acid stress. As more information is compiled on lake sensitivity to acid rain and the consequences for biological organisms, it will be included in the model structure.

The model was developed from data collected in the Muskoka-Haliburton region of Ontario, making it most suited to that area. However, because the model framework is based on the fundamental ecology of the lake-watershed system, the model (with some modification) can be applied to recreational inland lakes outside the study region. In addition, although the focus of the study was single-tier lakefront developments, the model could be adapted for the evaluation of multi-tier and cluster type development.

Finally, we want to stress that the OLCSM, in its present state, must not be considered as a tool to generate an "optimum number" but rather a process which will help test alternative management plans and hopefully predict impact and change. The predictions should be viewed as projections of general trends and not highly accurate lines. We make no pretenses about being able to accurately predict 20 years into the future. We do suggest that the OLCSM can predict trends based on present conditions.

It is anticipated that in the future the OLCSM will be updated and revised periodically in response to research developments that strengthen linkages among the variables, improve relationships, or reveal new factors which enhance the reliability of model predictions.

To facilitate use of the model, a user's guide describing the necessary commands and model format has been prepared (Teleki and Herskowitz, 1982).

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